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Time Delay Measurements of Current Primary FAA Air/Ground Transmitters and Receivers

John Petro
Philip Randazzo

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16. Abstract This report details the results of tests performed by ACW-300B, Spectrum Engineering Group, in determining the amount of time delay present in various air/ground communications equipment. This test was comprised of an Federal Aviation Administration (FAA) Air Navigation Ground Radio Transmitter (AN-GRT-21) and an FAA Air Navigation Ground Radio Receiver (AN-GRR-23): two aircraft transceivers, a King KTR-905 very high frequency (VHF) transceiver, and a Collins VHF-251 Technical Standard Order (TSO) transceiver.					
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1. INTRODUCTION.

1.1 PURPOSE.

The purpose of these measurements was to determine the amount of delay that is present in primary air/ground communications equipment presently being implemented by the Federal Aviation Administration (FAA).

1.2 BACKGROUND.

The FAA is presently in the process of upgrading various equipment used in air-to-ground and ground-to-air communications. As part of this upgrading, many communication units that were once purely analog are now being proposed as being a hybrid analog/digital device or as a purely digital device with only an analog output. In this upgrading process, the question has arisen as to what throughput time delays are present in the equipment the FAA is presently implementing in the field. To address this question, four representative FAA communication units were tested to determine their various time delays.

1.3 OBJECTIVE.

- a. Determine the time it takes for an FAA Air Navigation Ground Radio Transmitter (AN/GRT-21) ground transmitter to reach full radio frequency (RF) output power after the unit is keyed.
- b. Determine the amount of time required for an audio output to be produced from an FAA Air Navigation Ground Radio Receiver (AN/GRR-23) ground receiver after a modulated RF signal is presented to the receiver.
- c. Determine the time it takes for a typical aircraft transceiver to reach full RF output power after the unit is keyed.
- d. Determine the amount of time required for an audio output to be produced from a typical aircraft transceiver after a modulated RF signal is presented to the receiver.
- e. Determine the time required to establish the air-to-ground link between an aircraft transceiver and an AN/GRR-23 ground receiver.
- f. Determine the time required to establish the ground-to-air link between an AN/GRT-21 ground transmitter and an aircraft transceiver.

2. TEST SCENARIO.

2.1 TEST APPROACH.

Each piece of communications equipment was tested separately to determine its characteristic time delay. For receivers, the time required for an audio output to appear once a modulated RF signal was present, the characteristic time delay

was then measured. If the receiver under test had a squelch circuit, it was turned on for the entire test. For the transmitters, the time for maximum RF power to be available after the unit was keyed was also measured. Once this time delay was established, the ground units were tested in conjunction with the aircraft transceivers in order to verify the results obtained from testing the units separately.

2.1.1 Receiver Time Delay Measurements.

The receiver time delay was measured at the assigned frequency of the communications equipment under test. A coaxial switch was used to introduce modulated RF 1 kilohertz (kHz) tone, 30 percent amplitude modulation (AM) to the receiver under test. The use of the coaxial switch allowed the RF to be introduced in a more precise manner than turning the signal generator on from the front panel. This modulated RF was used to trigger a digital oscilloscope which recorded the subsequent output from the receiver audio output port. The use of the digital oscilloscope allowed the time delay between when the RF was introduced to the receiver, to the time the receiver produced an audio output of 1 kHz to be accurately measured. The squelch circuit was utilized for all receivers.

Figure 1 represents the test setup used to test the AN/GRR-23 receiver.

Figure 2 is the equipment configuration used to test the aircraft transceivers in the receive mode.

2.1.2 Transmitter Time Delay Measurements.

The transmitter time delay was measured using a digital storage oscilloscope and a keying circuit to enable the transmitter. Prior to keying the transmitter, the unit under test was configured to output a 1-kHz tone at 90 percent AM. The keying circuit served two functions: (1) enabled the transmitter under test, and (2) triggered the oscilloscope. Once the oscilloscope was triggered, the resulting RF power was recorded and stored. The digital oscilloscope allowed the time difference between when the keying circuit was enabled and when the transmitter reached full RF power to be measured.

Figure 3 represents the test setup used to test the AN/GRT-21 transmitter.

Figure 4 is the equipment configuration used to test the aircraft transceivers in the transmit mode.

2.1.3 Air-to-Ground Link Time Delay Measurements.

For the air-to-ground time delay measurement, an aircraft transceiver and an AN/GRR-23 receiver were used. A keying circuit was used to enable the transmitter section of the aircraft transceiver and to trigger the oscilloscope. The transmitter was configured to output a 1-kHz tone at 90 percent AM. Once triggered, the oscilloscope recorded the audio output of the receiver. The time delay between, when the transceiver was keyed to transmit and when the ground receiver outputted a 1-kHz tone, was then measured.

Figure 5 represents the test configuration for this test.

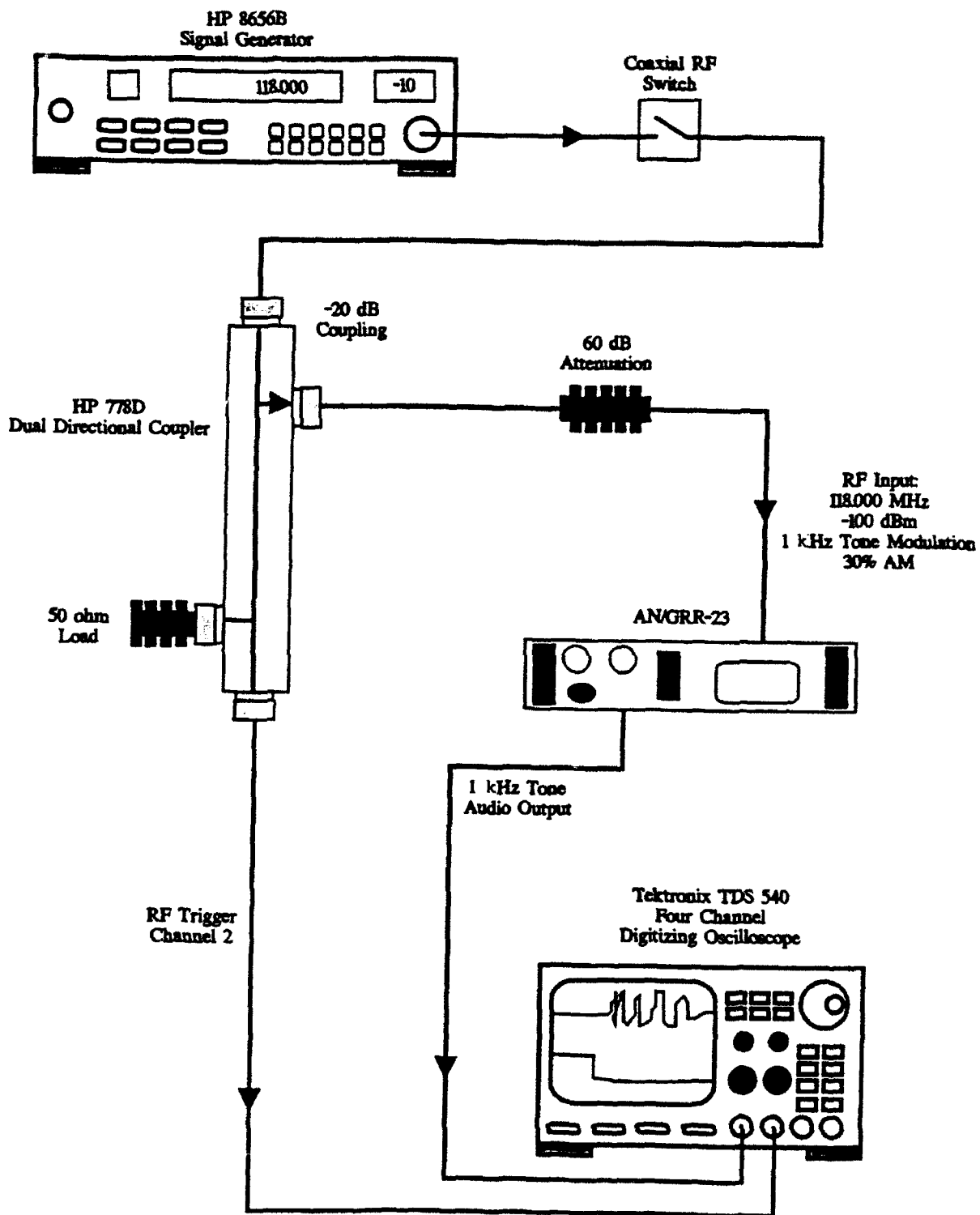


FIGURE 1. AN/GRR-23 TEST SETUP

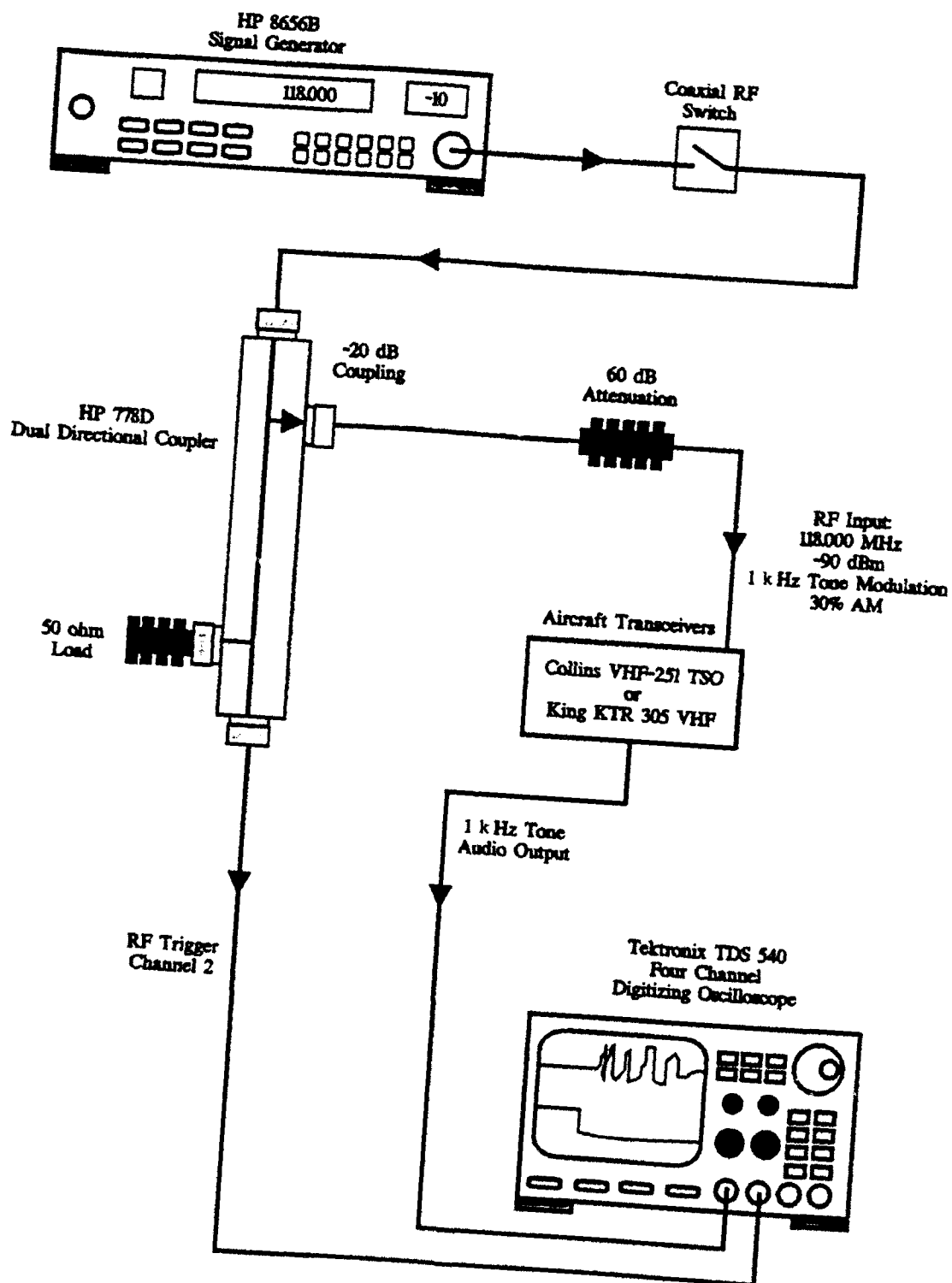


FIGURE 2. AIRCRAFT TRANSCEIVER-RECEIVER TEST SETUP

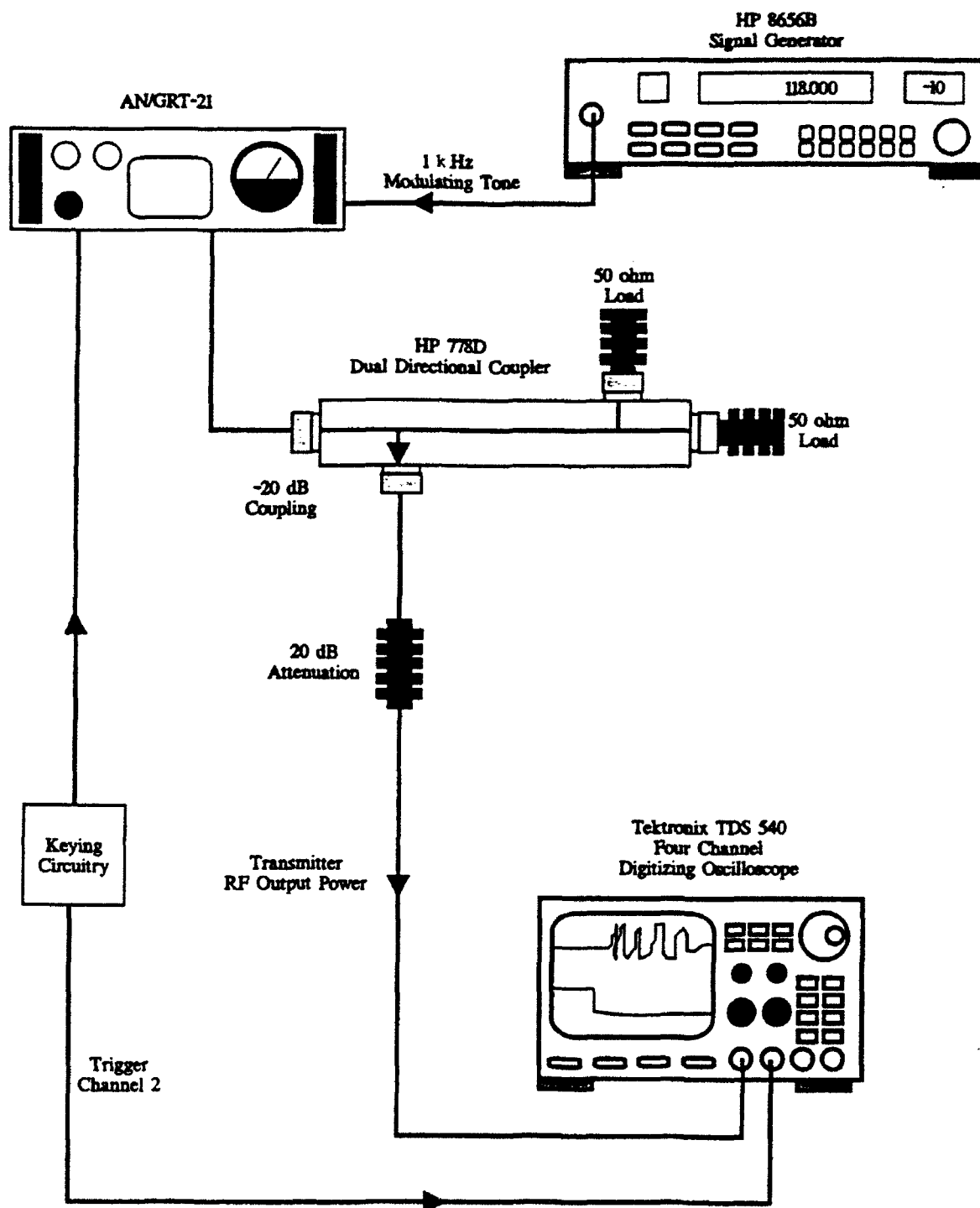


FIGURE 3. AN/GRT-21 TEST SETUP

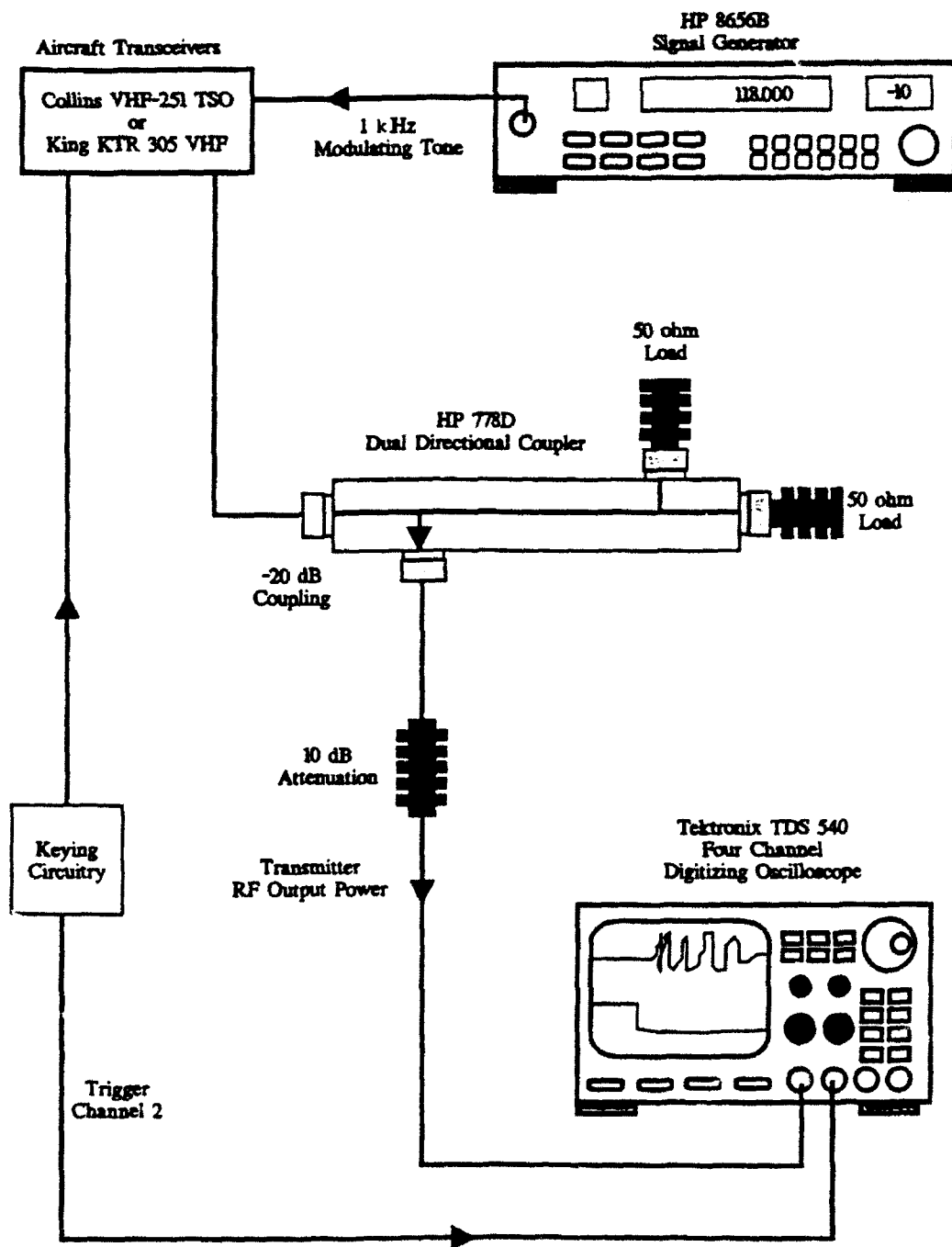


FIGURE 4. AIRCRAFT TRANSCEIVER-TRANSMITTER TEST SETUP

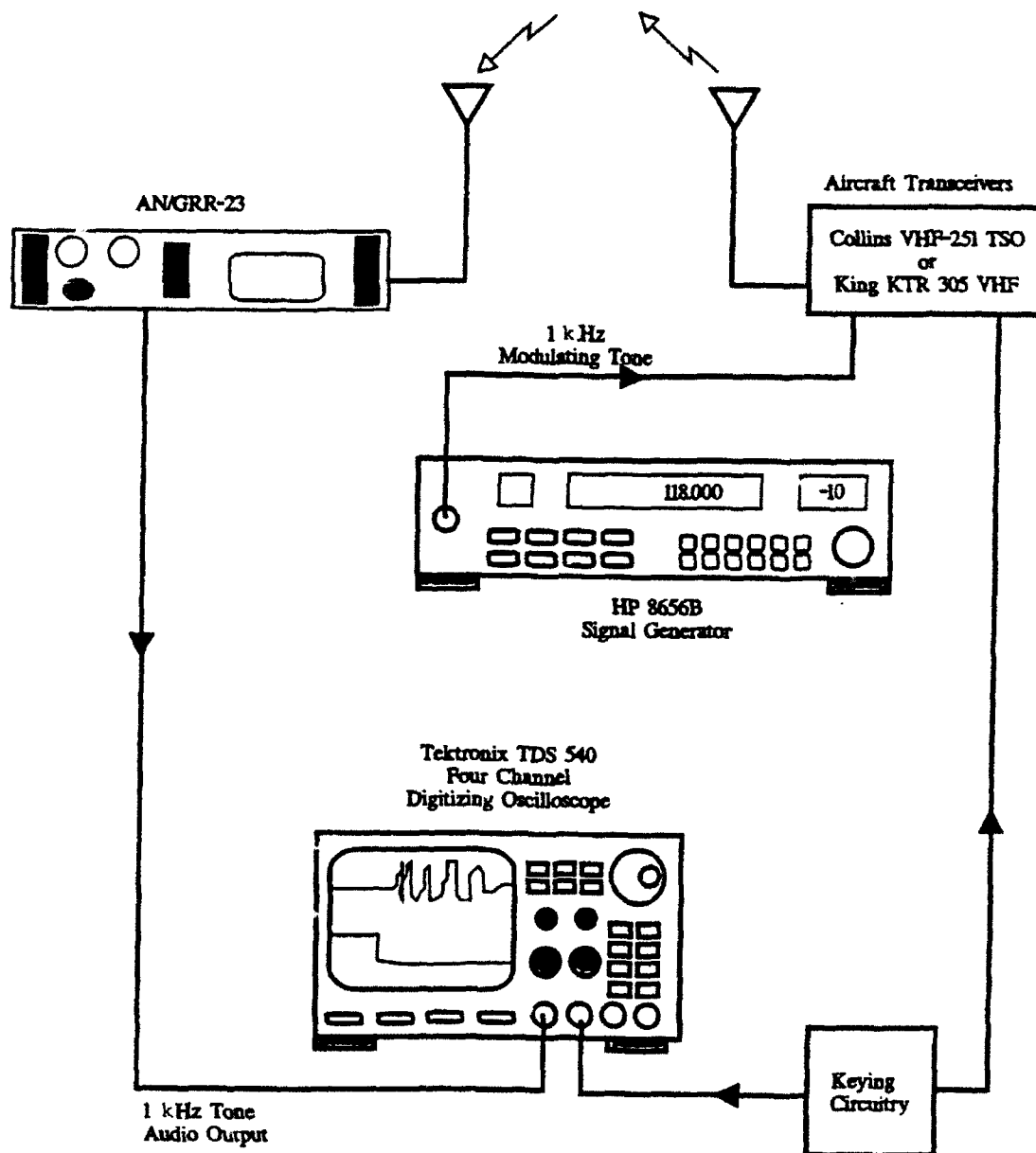


FIGURE 5. TRANSCEIVER AIR-TO-GROUND TEST SETUP

2.1.4 Ground-to-Air Link Time Delay Measurements.

For the ground-to-air time delay measurement, an aircraft transceiver and an AN/GRT-21 transmitter were used. A keying circuit was used to enable the transmitter and to trigger the oscilloscope. The transmitter was configured to output a 1-kHz tone at 90 percent AM. Once triggered, the oscilloscope recorded the audio output of the receiver section of the transceiver. The time delay between, when the transmitter was keyed to transmit and when the transceiver outputted a 1-kHz tone, was then measured.

Figure 6 shows the equipment configuration for this test.

2.2 EQUIPMENT DESCRIPTION.

The equipment used for these tests included FAA ground communication units, aircraft transceivers, and test equipment.

2.2.1 FAA Ground Communication Equipment.

The transmitter and receiver tested were FAA standard air traffic control communications equipment manufactured by International Telephone and Telegraph (ITT) Corporation. The AN/GRT-21 is a 10-watt crystal-controlled amplitude modulated transmitter. The AN/GRR-23 is a crystal-controlled, single-channel, superheterodyne receiver operating in the amplitude modulated mode.

2.2.2 Aircraft Transceivers.

To represent the aircraft transceivers currently in use, two units were chosen. The first unit was a Collins very high frequency (VHF)-251 Technical Standard Order (TSO) communications transceiver and the second unit was a King KTR-905 VHF communications transceiver.

2.2.3 Test Equipment.

The equipment used to make the time delay measurements consisted of the following: one Hewlett Packard 8656B signal generator, one Hewlett Packard 778D dual directional coupler, and one Tektronix TDS540 four-channel digital oscilloscope.

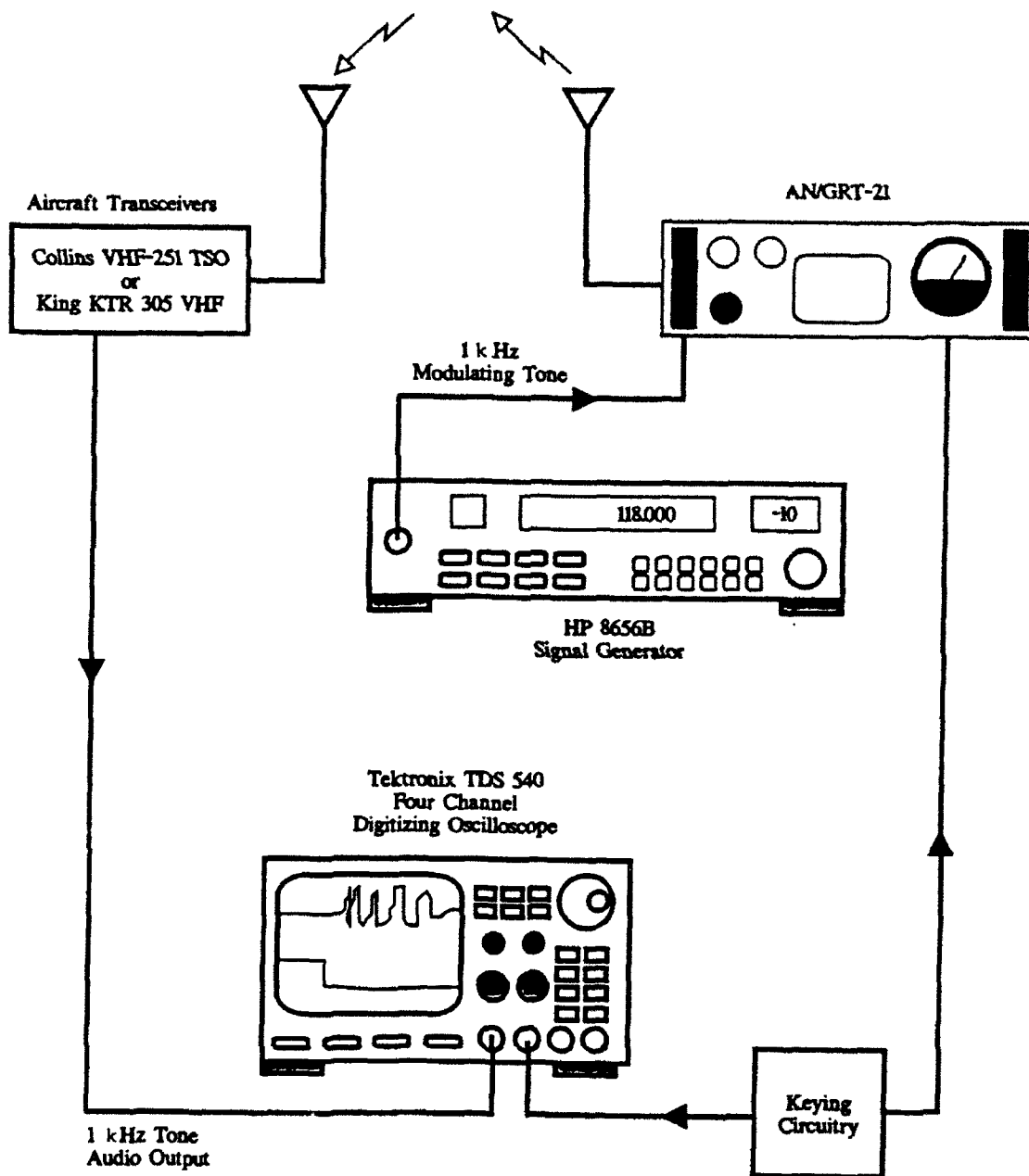


FIGURE 6. TRANSCEIVER GROUND-TO-AIR TEST SETUP

3. DATA RESULTS.

3.1 GENERAL RESULTS.

Figures 7 through 16 are graphical representations of the data collected from all the aforementioned time delay tests. These graphs are hard copies directly outputted from the digital oscilloscope at the time the measurements were completed. Figure 7 shows the receiver time delay of the AN/GRR-23 to be 125 millisecond (ms). Figures 8 and 9 show the results of the aircraft transceivers being used in the receive mode. The Collins VHF-251 transceiver exhibited a time delay of 30 ms, while the King KTR-905 TSO presented a delay of 168 ms. The 1-kHz audio output from the Collins VHF-251 in figure 8 shows the automatic gain control (AGC) circuitry affecting the amplitude of the audio output during the first 40 to 50 ms of the 1-kHz output. The FAA AN/GRT-21 transmitter time delay results are shown in figure 10. The measured delay of the AN/GRT-21 was 28.8 ms. The transmitter time delay of the aircraft transceivers being used in the transmit mode are shown in figures 11 and 12. The King KTR-905 TSO transmitter time delay was measured as being 84.8 ms. The King KTR-905 TSO began to transmit earlier than 84.8 ms after the trigger, but the RF power was not consistent before this time and, therefore, was not chosen as the beginning of the RF output waveform. This inconsistency is believed to be due to the internal oscillator of the transceiver coming up to its operating frequency. The Collins VHF-251 measured transmitter delay was 34.4 ms. The oscilloscope trace shows that the Collins VHF-251 outputted some type of voltage just prior to its outputting the required RF waveform. As can best be determined, this output is the result of the transmitter being powered up by its own internal circuitry while its oscillator has not arrived at the proper operating frequency.

Figures 13 and 14 show the results of the ground-to-air link time delay measurements. Figure 13 indicates the time delay of the ground-to-air link of the King KTR-905 TSO as being 196 ms. The time delay of the Collins VHF-251 was measured as 75 ms as shown in figure 14.

Figures 15 and 16 show the results of the air-to-ground link time delay measurements. The Collins VHF-251, figure 15, shows a time delay of 160 ms. The King KTR-905 TSO, figure 16, shows a time delay of 190 ms.

The top oscilloscope trace in figures 7, 9, 13, 14, 15, and 16 is of the 1-kHz audio output from the receivers under test. In each of the traces, the 1-kHz audio output appears to be differing in frequency from the required 1-kHz to a low frequency of approximately 6 hertz (Hz). This apparent error in frequency is the result of oscilloscope aliasing, or undersampling of the 1-kHz waveform. In order to avoid aliasing, the horizontal time division on the oscilloscope would have to be made smaller; i.e., change from 50 ms per division to 500 microsecond (μ s) per division. This would have resulted in the 1-kHz waveform being correctly sampled, but the number of division between when the trigger occurred and when the resultant waveform was outputted from the receiver would not have fit on the oscilloscope screen due to its limit of only 10 divisions per screen. Since the focus of the report is on the time delay present in different transceivers, both the triggering waveform and the resultant waveform were positioned on the same screen for clarity.

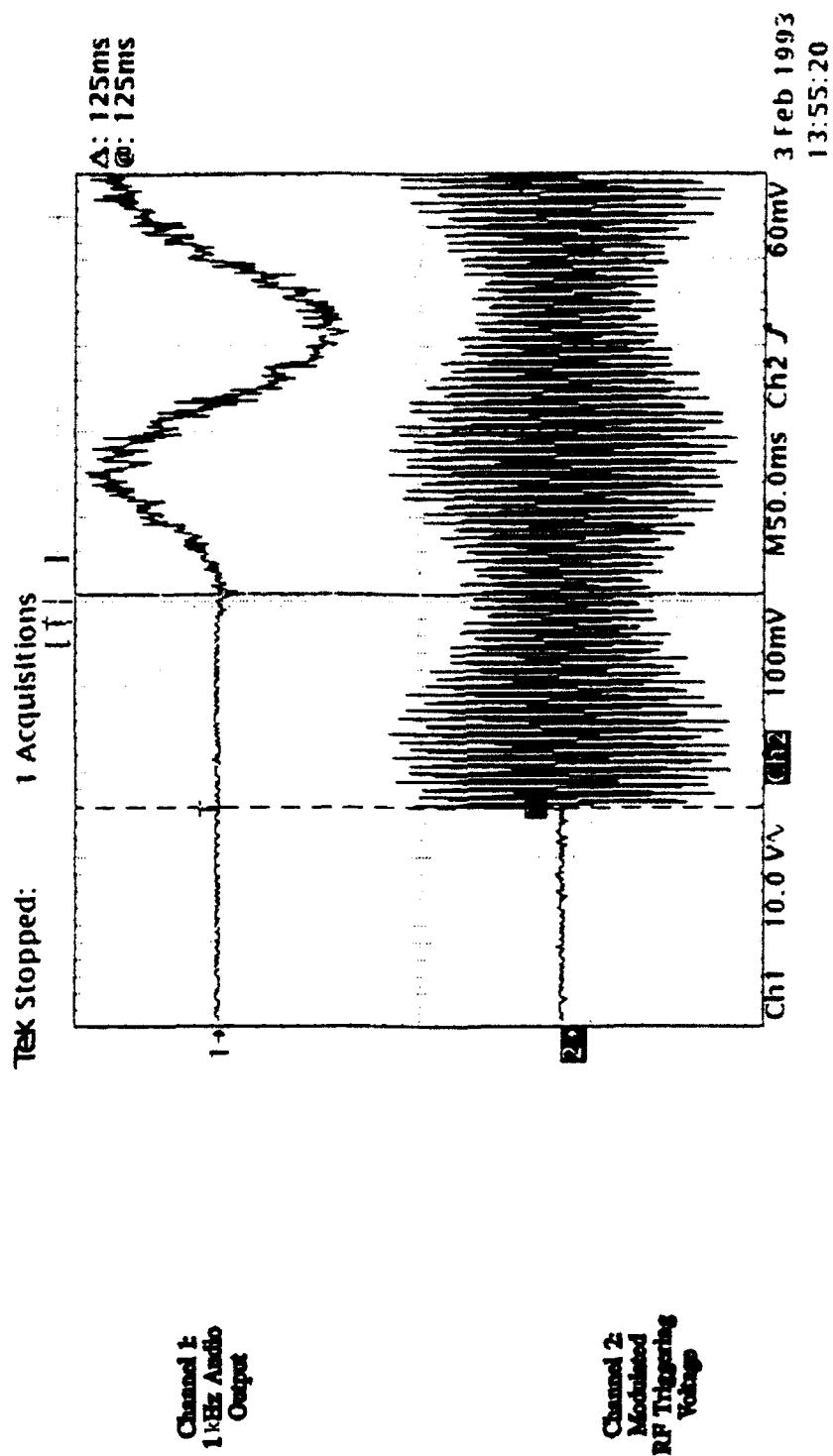


FIGURE 7. AN/GRR-23 RECEIVER TIME DELAY

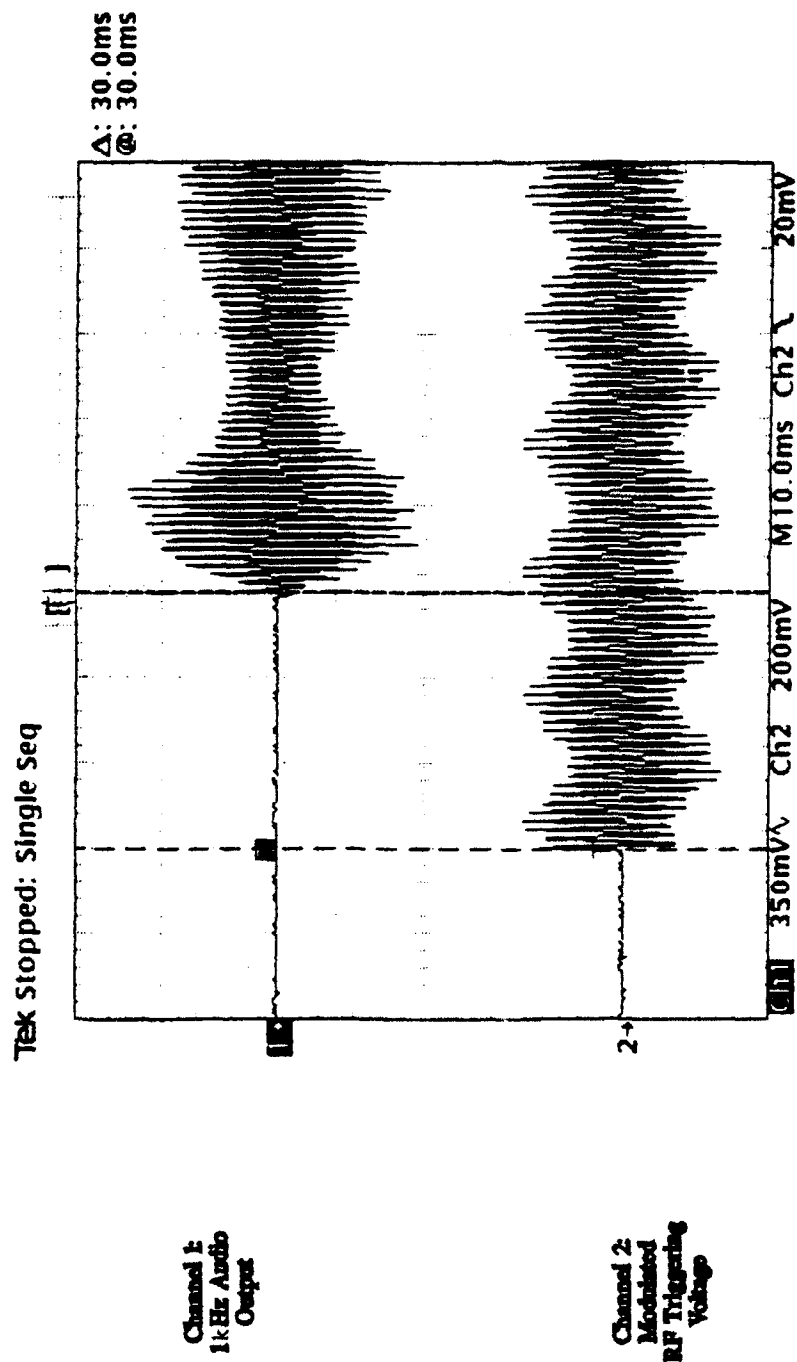


FIGURE 8. COLLINS VHF-251 TSO RECEIVER TIME DELAY

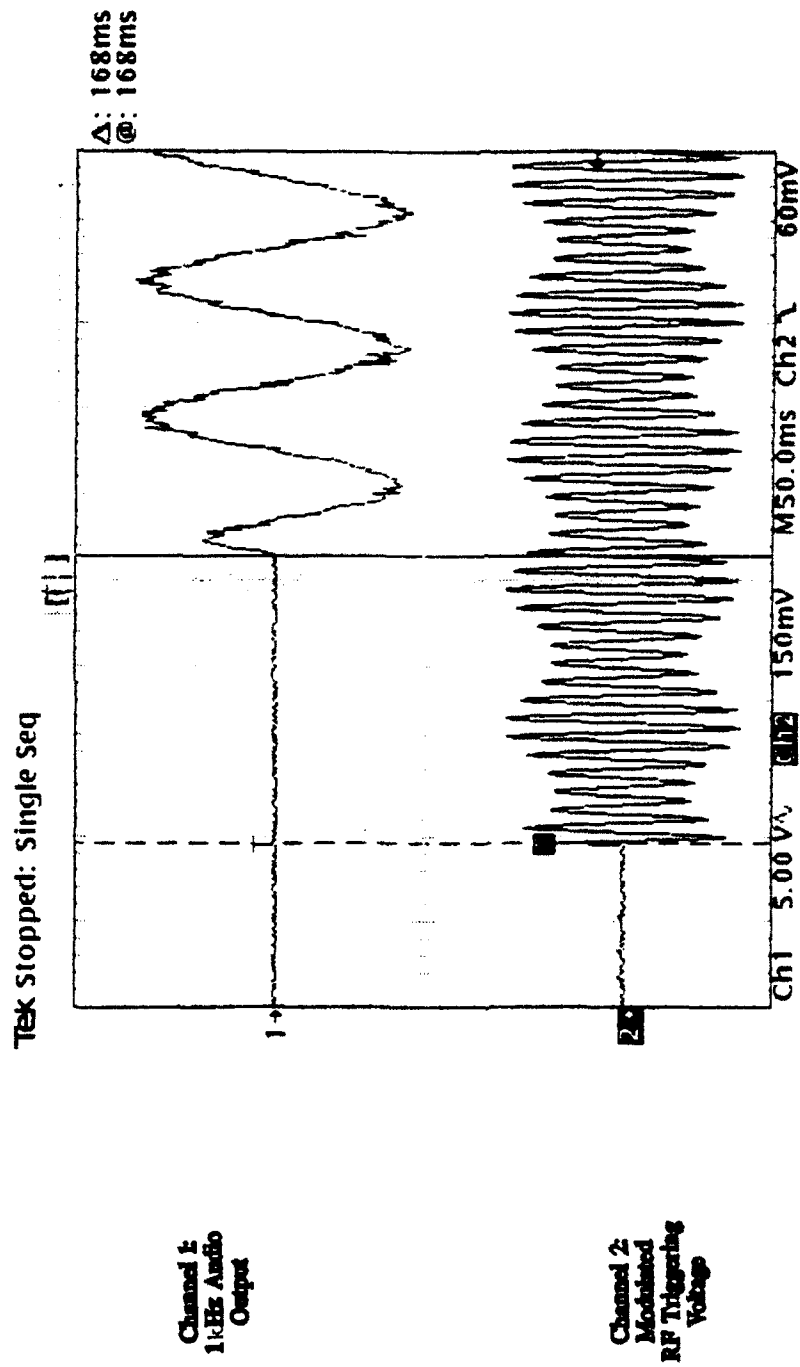


FIGURE 9. KING KTR-905 TSO VHF RECEIVER TIME DELAY

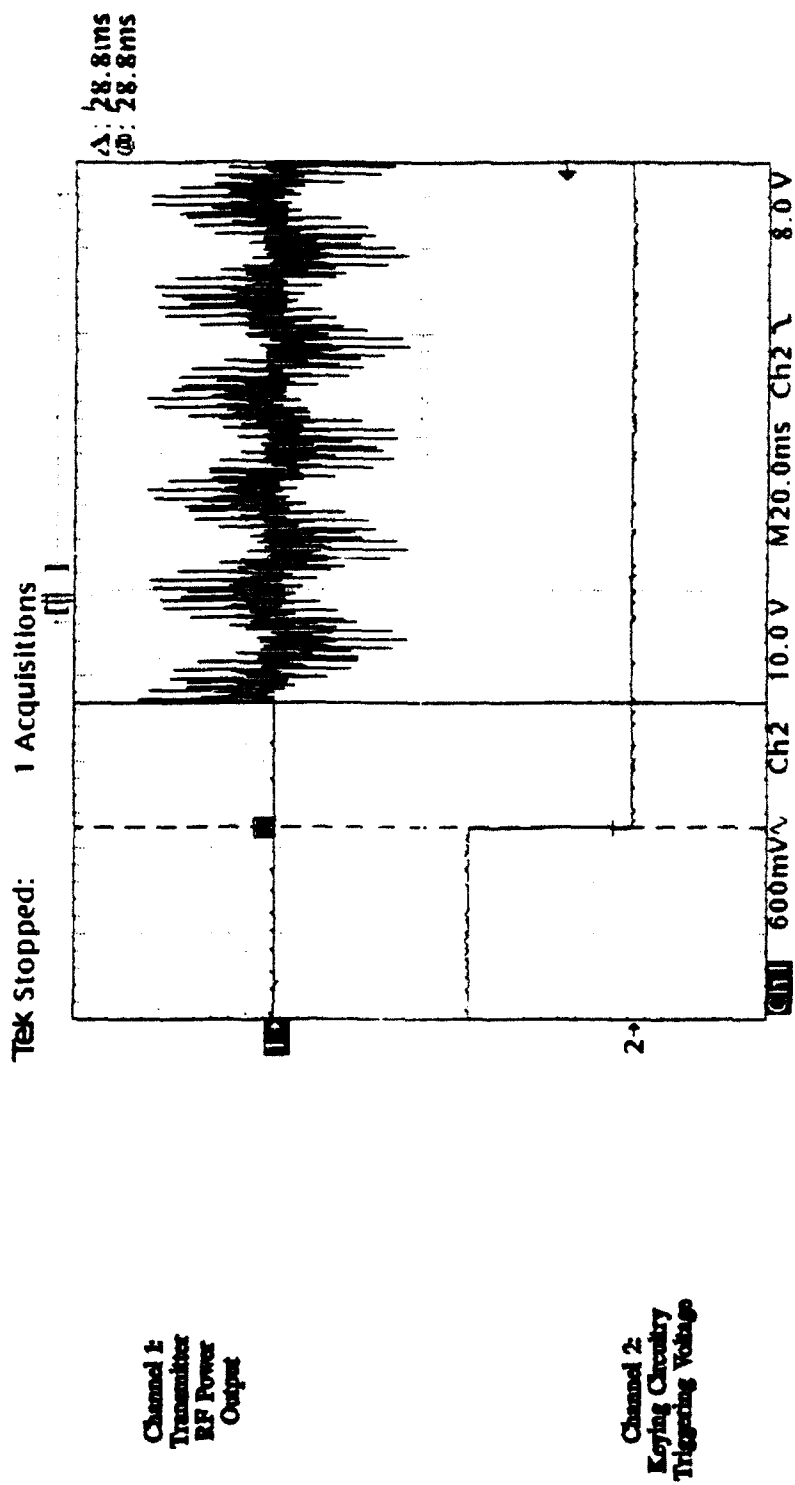


FIGURE 10. AN/GRT-21 TRANSMITTER TIME DELAY

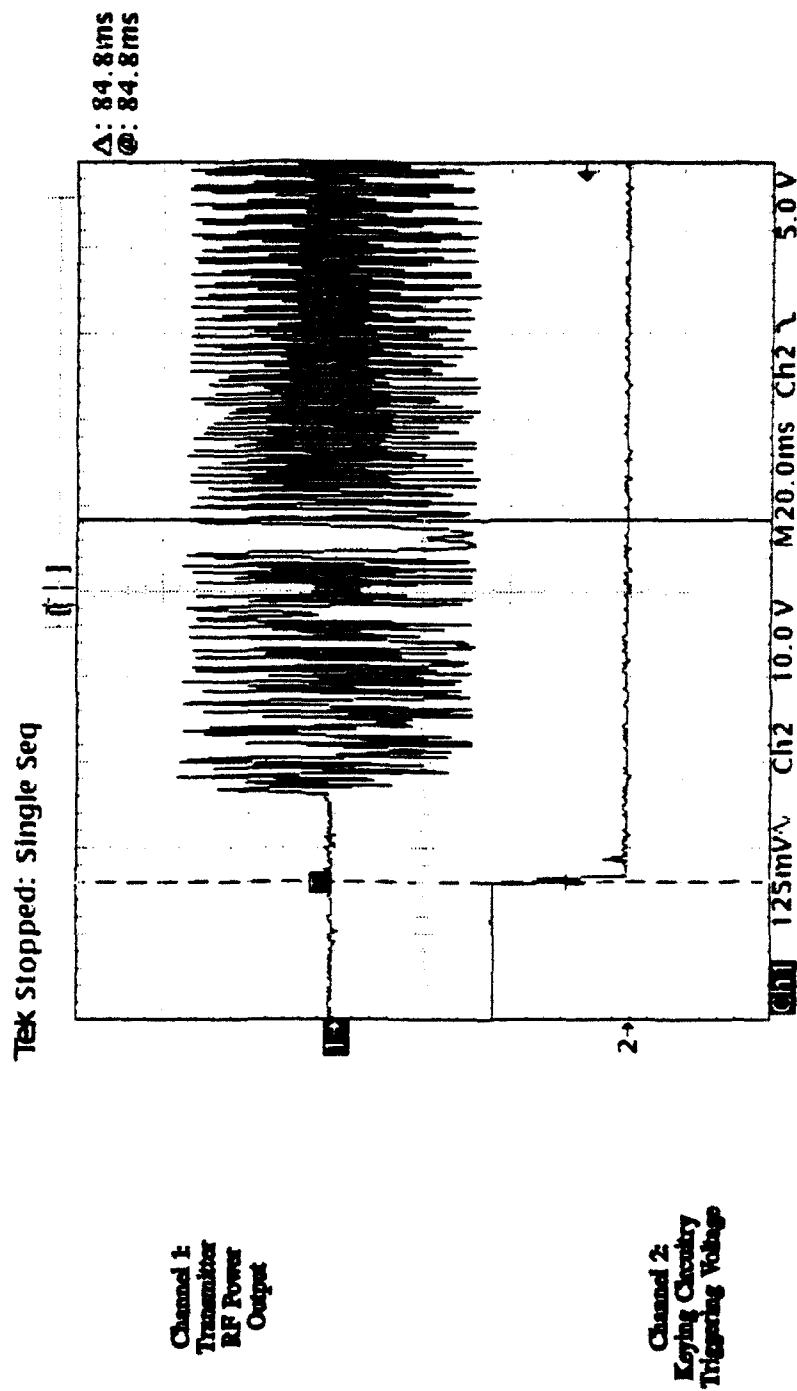


FIGURE 11. KING KTR-905 TSO VHF TRANSMITTER TIME DELAY

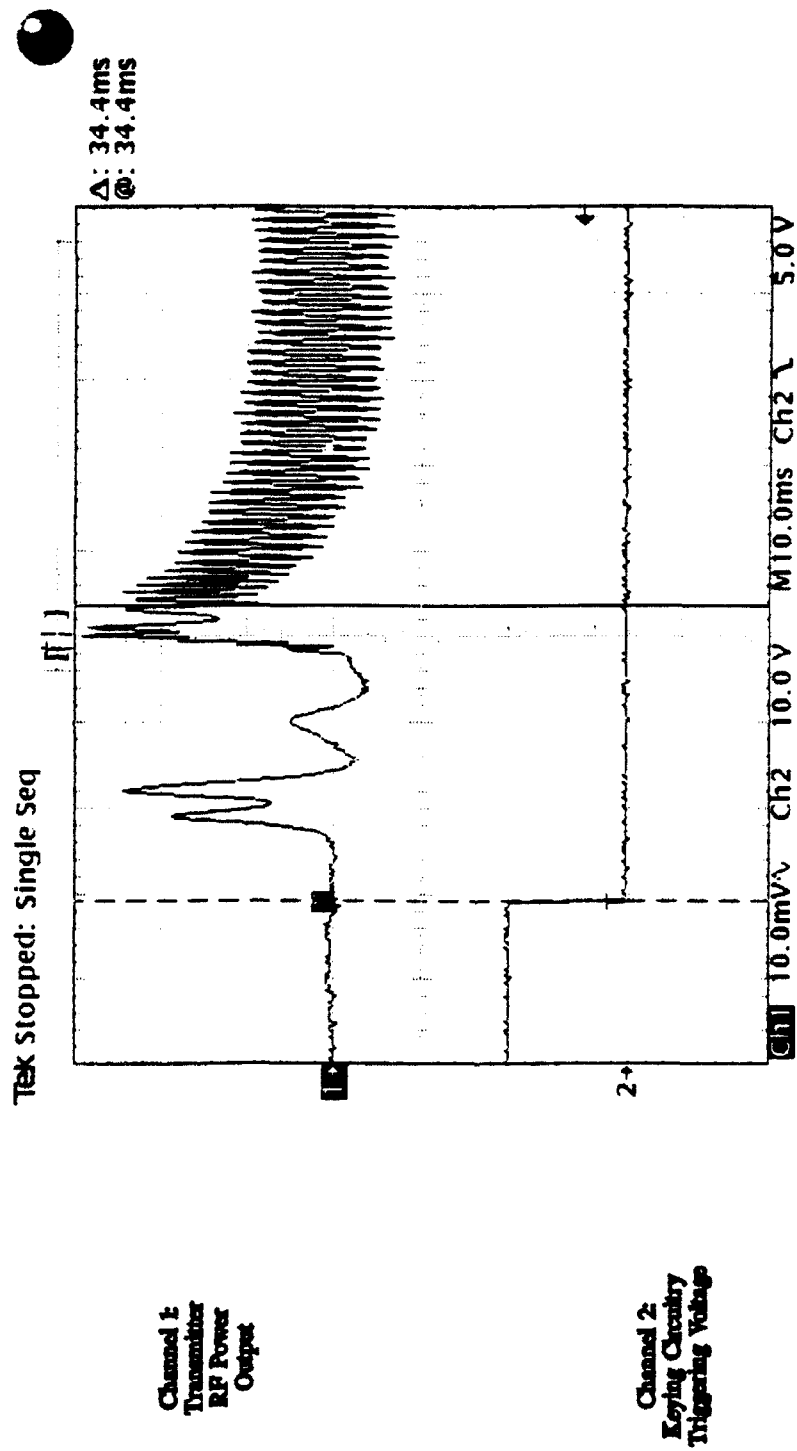


FIGURE 12. COLLINS VHF-251 TSO TRANSMITTER TIME DELAY

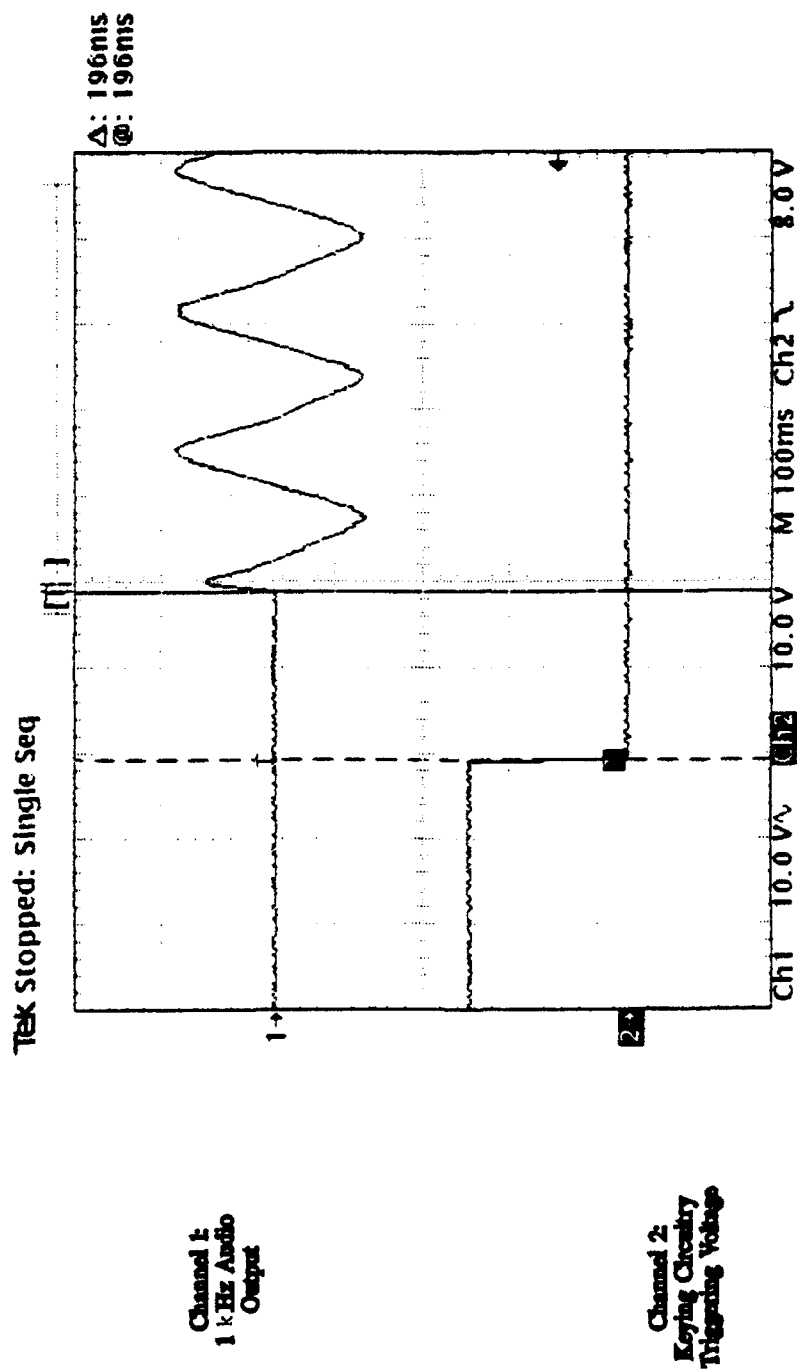


FIGURE 13. KING KTR-905 TSO VHF GROUND-TO-AIR LINK TIME DELAY

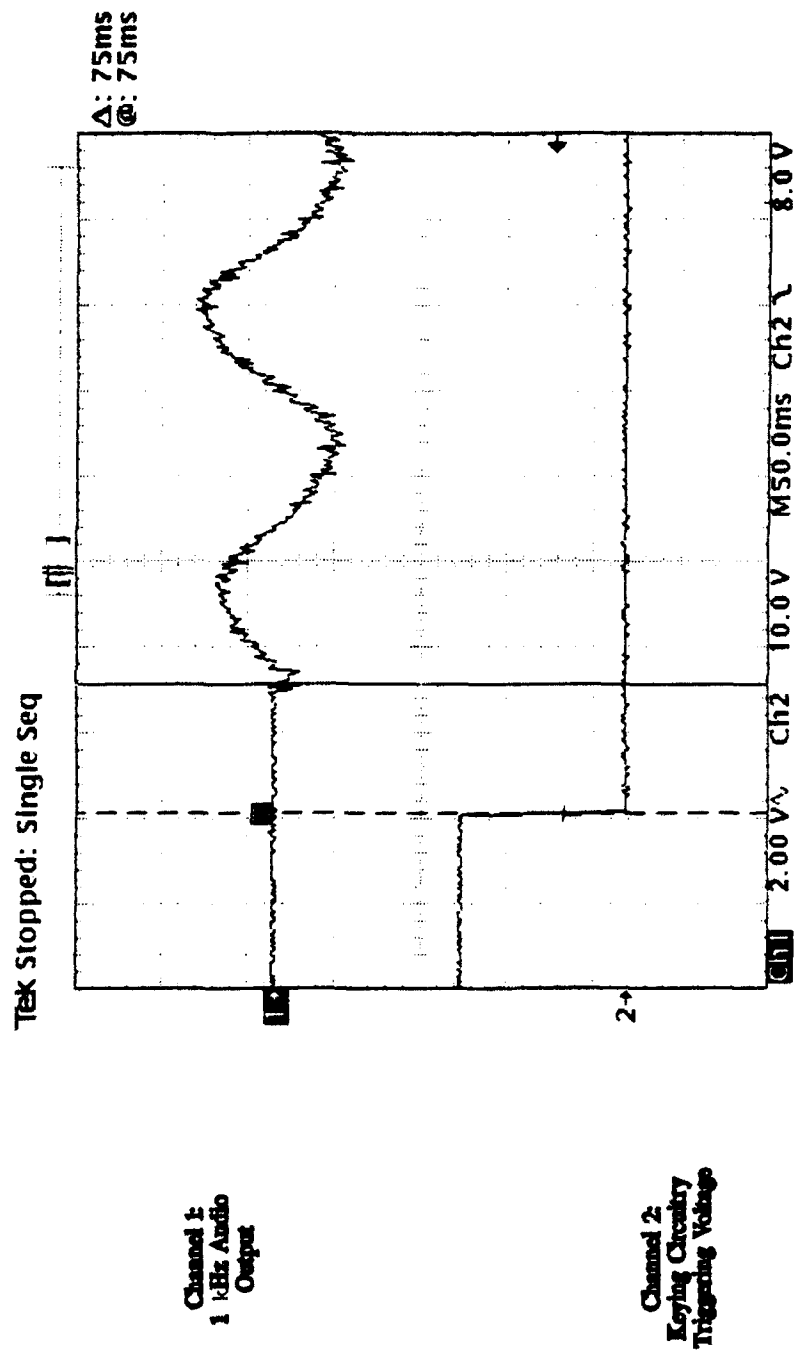


FIGURE 14. COLLINS VHF-251 TSO GROUND-TO-AIR LINK TIME DELAY

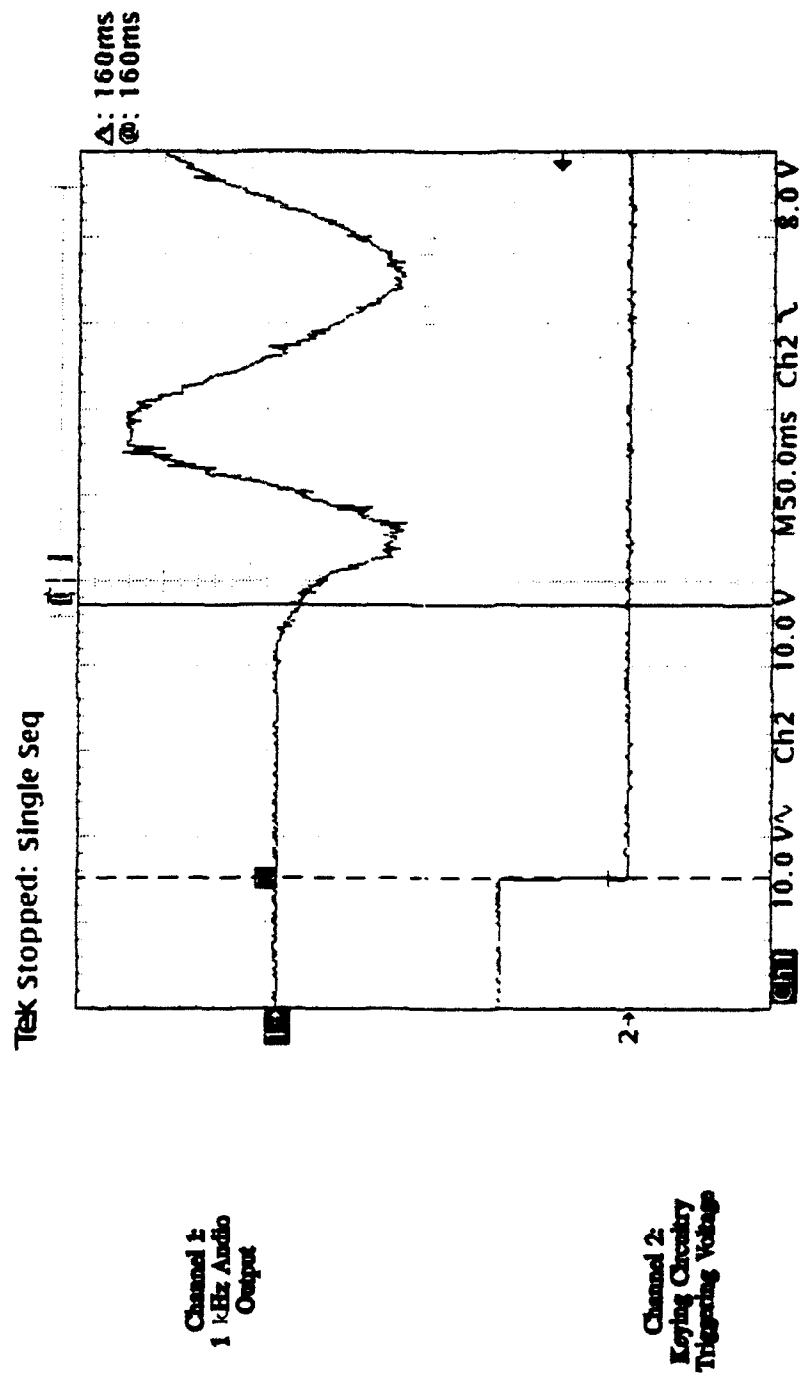


FIGURE 15. COLLINS VHF-251 TSO AIR-TO-GROUND LINK TIME DELAY

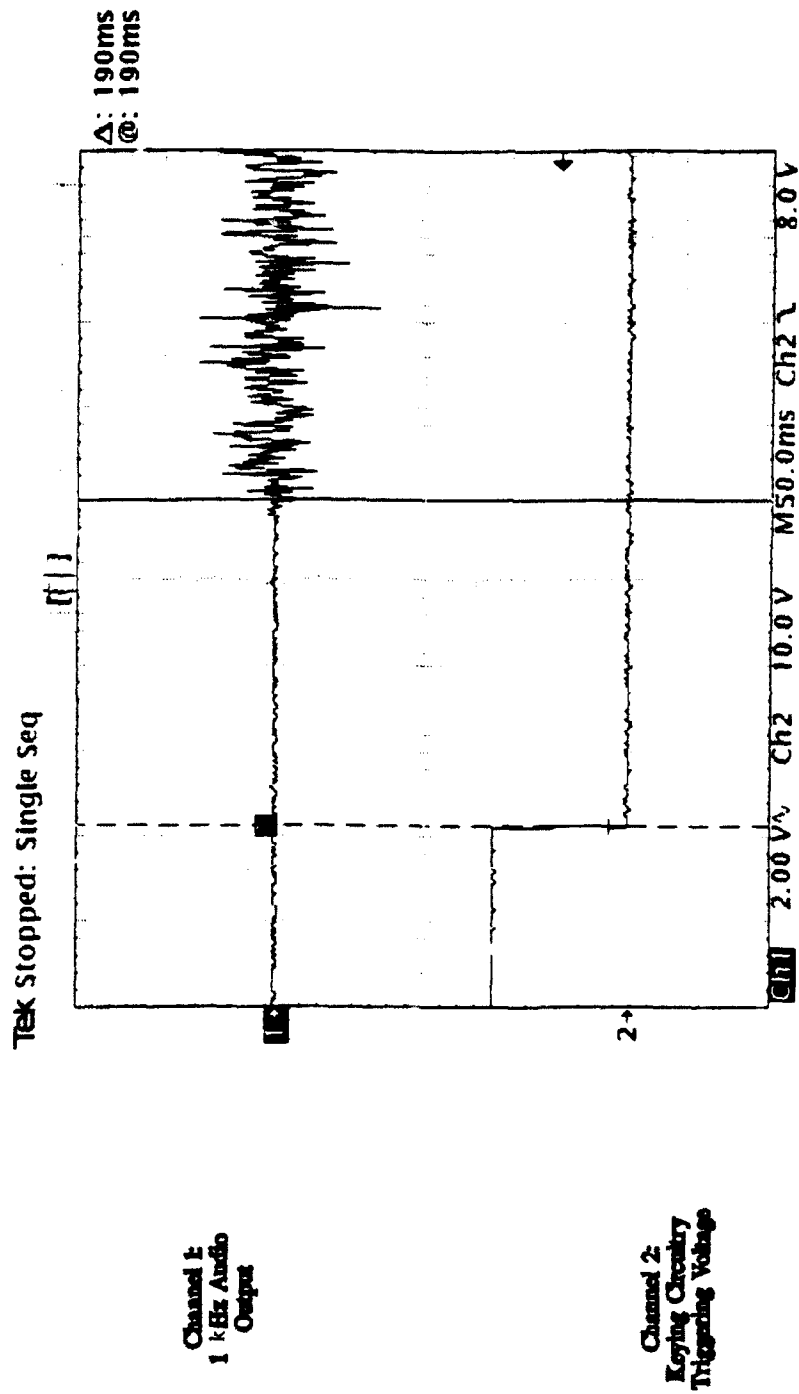


FIGURE 16. KING KTR-905 TSO VHF AIR-TO-GROUND LINK TIME DELAY

The table below is a summary of all the time delays measured during the test.

TABLE 1. TIME DELAY SUMMARY

Measurement: Unit Tested:	Transmitter Time Delay	Receiver Time Delay	Ground-to-Air Link Time Delay	Air-to-Ground Link Time Delay
AN/GRR-23	X	125ms	X	X
AN/GRT-21	28.8ms	X	X	X
Collins VHF-251	34.4ms	30.0ms	75ms	160ms
King KTR 905	84.8ms	168ms	196ms	190ms

It should be noted that the air-to-ground time delay and the ground-to-air time delay will show a slight difference as compared to when the receiver and transmitter time delays are added together separately. This difference is attributable to when the correct output was judged to be starting on the oscilloscope for each measurement. To maintain consistency, the very beginning of the waveform was chosen as the start of the required output. Despite this, there is still a slight difference between the two methods.

3.2 CONCLUSION.

The results of tests indicate the time delays measured are inherent characteristics of the particular unit under test. Receiver time delays varied from a low of 30.0 millisecond (ms) to a high of 168 ms. Transmitter time delays varied from 28.8 ms for a low to 84.8 ms for a high.